The 63rd Annual
Merck State Science Day Competition
May 23, 2013

ADVANCED INTEGRATED SCIENCE

Directions:To register as a student:
You will need to ask your teacher for the school phone number used as an identifier for your school.
Fill out the form using your normal email address but please use a password that is NOT associated with any other secure accounts (Your MSSD password).
You must also select the test you will be taking at this time.

On the day of the MSSD competition:
You will be asked to login using your email address and your MSSD Password.
You are encouraged to register early and to log into your test page. Try the Demo Test if you have not already done so.In this demo test, answers are not saved. In a regular test, each answer is stored when **Submit** is used.
When finished, select **FINISHED TEST** in lower left.

Using the Answer Panel
The Demo Test "answer panel" at the bottom of the window is pre-set to show 3 answer boxes per page. (A normal test may show 10 or more answers per page.)
1. The current question has a black border.
2. Questions that have been answered will be tinted **Green**
3. Click **Submit** to record your answer and scroll to the next test question (even if it is on the next page).
4. Any answer can be edited. Delete your original choice, enter your new letter choice, then **Submit** the correction.
5. **>** moves to the next set of questions (**<** moves back)
6. Click on any number to answer that question.
Hint: The size of the lettering in the bottom answer panel can be adjusted using CTRL + to magnify the browser view. The TEST view can be adjusted using the size control in the PDF viewer (eg Adobe Reader).

INFORMATION THAT MAY BE USEFUL IN SOLVING SOME PROBLEMS(on back also)

1 calorie = 4.184 joules

$1/f = 1/d_o + 1/d_I$

$C = 2f$

$h_i/h_o = d_i/d_o$

$E = hf$

speed of light in vacuum = 3.0×10^8 m/sec

Planck's constant, h = 6.63×10^{-34} joule-sec

$v = c \sqrt{1 - v^2/c^2}$

Avogadro's Number = 6.02×10^{23}

$Q = mc\Delta T$

$KE_{ave} = 1/2mv^2$

$PE_{grav} = mgh$

$W = F \times S$

$W = Vq$

$v_{avg} = s/t$

$s = v_o t + 1/2at^2$

$v_f^2 = v_i^2 + 2as$

$v_f = v_i + at$

$c = f\lambda$

$P_1V_1/T_1 = P_2V_2/T_2$

$I = V/R$

$1 C = 6.25 \times 10^{18}$ e$^-$

$D = M/V$

$v = f\lambda$

$P = W/t$

K_f water = -1.86 °C/m

K_b water = 0.51°C/m

Universal gas constant: R = 8.31 kPa-liter/(mole-K) = 0.0821 atm-liter/(mole-K)

The Periodic Table of the Elements

1 H Hydrogen 1.00794																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
11 Na Sodium 22.989770	12 Mg Magnesium 24.3050											13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.845	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 La Lanthanum 138.9055	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				

58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Multiple Choice
*Identify the choice that best completes the statement or answers the question and place your selection in the answer window on the computer, then **SUBMIT.***

I. *Hydraulic fracturing is the propagation of fractures in a rock layer, by a pressurized fluid. Some hydraulic fractures form naturally. **Induced hydraulic fracturing** or **hydrofracturing**, commonly known as **fracking**, is a technique used to release petroleum, natural gas or other substances for extraction..*

The technique of hydraulic fracturing is used to increase or restore the rate at which fluids, such as petroleum, water, or natural gas can be produced from subterranean natural reservoirs. Reservoirs are typically porous sandstones, limestones or dolomite rocks, but also include "unconventional reservoirs" such as shale rock or coal beds.

Proponents of hydraulic fracturing point to the economic benefits from vast amounts of formerly inaccessible hydrocarbons the process can extract. Opponents point to potential environmental impacts, including contamination of ground water, risks to air quality, the migration of gases and hydraulic fracturing chemicals to the surface

Injection of radioactive tracers, along with the other substances in hydraulic-fracturing fluid, is sometimes used to determine the injection profile and location of fractures created by hydraulic fracturing. Radioactive isotopes chemically bonded to glass (sand) and/or resin beads may also be injected to track fractures.[For example, plastic pellets coated with 10 GBq of Ag-110mm may be added to the proppant or sand may be labelled with Ir-192 so that the proppant's progress can be monitored.

1. The half-life of Ir-192 is 73.83 days. How much of the 1.50 kg sample is left after 1 year?
   A) 3.26 g
   B) 4.89 g
   C) 11.9 g
   D) 16.1 g
   E) 48.9 g

2. 95% of the time, Ir-192 decays by ß emission, the other 5%, it decays by electron capture. What would be the daughter elements of it's decays?
   A) Pt-192, Ir-191
   B) Os-192, Pt-192
   C) Pt-192, Au-192
   D) Os-192, Re-191
   E) Re-188, Os-192

3. Ethylene glycol (1,2-dihydroxyethane), $C_2H6O_2,$ is used to prevent the formation of scale deposits in the pipes. It works because it
   A) has a double bond
   B) is basic
   C) has 2 hydrogen bonds
   D) lowers the freezing point of the system
   E) forms a complex with the iron in the metal pipe

4. Acids (typically HCl and CH_3COOH) are used in the pre-fracturing stage for cleaning the perforations and initiating fissure in the natural reservoirs containing limestone. What would be the main gaseous product of this reaction?
   A) H_2O
   B) CO_2
   C) Cl_2
   D) $CaCH_3COO$
   E) $CaCl_2$

5. Glutaraldehyde (pentane-1,5-dial) is used as a disinfectant of the water used in fracking. What is its chemical formula?
   A) $OCHCH_2CH_2CH_2CHO$
   B) $HOCH_2CH_2CH_2CH_2CH_2OH$
   C) $OCH_2CH_2CH_2CH_2CH_2O$
   D) $CH_3OCH_2CH_2CH_2OCH_3$
   E) $CH_2OHCH_2CH_2CH_2OHCH_2$

6. Fossil fuels obtain via fracking are found in
   A) metamorphic rock.
   B) igneous rock.
   C) sedimentary rock.
   D) confined aquifers.
   E) unconfined aquifers.

7. Which of the following are additional environmental concerns directly associated with fracking?
       i. aquifer contamination
       ii. increased risk of seismic events.
       iii. cultural eutrophication.

   A) only one of the above.
   B) i and ii only.
   C) ii and iii only.
   D) all of the above.
   E) none of the above.

8. A pipe of radius $7R$ carries a uniformly dense liquid to a nozzle of radius R at the same height to begin the fracking process. At the nozzle, the liquid flows with a velocity of V. What was the velocity of the liquid through the $7R$ pipe?

   A) 0.02 V
   B) 0.11 V
   C) V
   D) 7 V
   E) 49 V

9. Which of the following is a properly reduced SI unit for pressure?

   A) $\dfrac{kg}{m^2}$

   B) $\dfrac{kg}{m \cdot s}$

   C) $\dfrac{kg}{s^2}$

   D) $\dfrac{kg}{m \cdot s^2}$

   E) $\dfrac{m \cdot s}{kg}$

10. The pressure in a pipe carrying a fracking liquid with a density of $ñ$ and an initial velocity v at the inlet is P, which is y meters lower than its outlet, which has a velocity of $2v$. In these terms, what is the final pressure?

   A) $\dfrac{P\rho(3v^2 + 2gy)}{2}$

   B) $P - \dfrac{\rho(3v^2 + 2gy)}{2}$

   C) $P + \dfrac{\rho(-3v^2 + \rho gy)}{2}$

   D) $\dfrac{\frac{1}{2}\rho(v^2 - 4v^2) - \rho gy}{P}$

   E) $P\left[\frac{1}{2}\rho(v^2 - 4v^2) - \rho gy\right]$

11. A fluid flows steadily from left to right in a pipe. The diameter of the pipe decreases steadily till it is one-half the original diameter and the fluid density is constant throughout the pipe. How do the velocity of flow, v, and the pressure, P, from the left side L (larger diameter) to the right R (smaller diameter) compare?

A) $v_L < v_R$ & $P_L = P_R$
B) $v_L < v_R$ & $P_L > P_R$
C) $v_L = v_R$ & $P_L < P_R$
D) $v_L > v_R$ & $P_L = P_R$
E) $v_L > v_R$ & $P_L > P_R$

12. Fracking causes an increased risk of ground water contamination because
A) fossil fuels may spill during transfer and transport.
B) deforestation needed for fracking equipment creates soil erosion.
C) fracking fluids may leak from the injection pipes.
D) all of the above.
E) none of the above.

13. Fossil fuels obtained via fracking were formed during the _____ era.
A) Precambrian
B) Paleozoic
C) Mesozoic
D) Cenozoic
E) Quaternary

II. *Oil and water usually don't mix, but when the two end up together, say in an oil spill or in an emulsion, they can be nearly impossible to completely separate. However, by combining a water-loving polymer with an oil-repelling silicon-based material, researchers this year created a new breed of membrane that efficiently separates bulk amounts of any type of oil-water mixture by simple gravity filtration. A team at the University of Michigan and the Air Force Research Laboratory devised membranes that sidestep typical membrane limitations—fouling by viscous materials and the energy cost of pumping liquids through the membrane—by dipping polyester fabric or stainless steel mesh in a mixture of cross-linked polyethylene glycol diacrylate, which is hydrophilic, and a fluorinated polyhedral oligomeric silsesquioxane, which is oleophobic (C&EN, Sept. 3, page 9; Nat. Commun., DOI: 10.1038/ncomms2027). When an oil-water mixture or emulsion is poured onto one of the membranes, microcrystalline regions reconfigure to form a smooth, noncrystalline surface that allows the polymer to hydrogen bond with water. Water then flows unimpeded through the membrane, which holds back the oil and is resistant to fouling. The researchers envision the membranes being used not only to clean up oil spills but also to treat wastewater, purify fuels, and separate emulsions used in manufacturing processes.*

14. What is the main reason that oil and water are usually immiscible?
A) oil in a complex substances and water is a pure substance
B) water has hydrogen bonds
C) oil is flammable and water is not
D) water is polar and oil is not
E) the molar entropy of oil is larger than that of water

15. The structural formula for polyethylene glycol diacrylate is
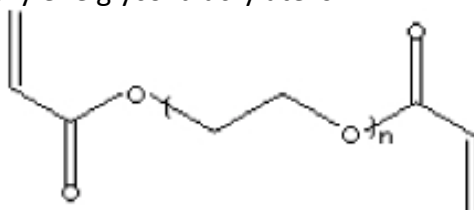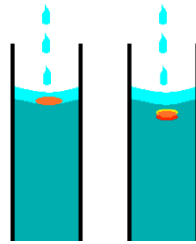

What is the molecular formula?
A) $CH_2CH_2COO[CH_2CH_2O]_nCOCH_2CH_2$
B) $CH_2CHCOO[CH_2CH_2O]_nCOCHCH_2$
C) $CH_3CH_2COO[CH_2CH_2O]_nCOCH_2CH_3$
D) $CH_2CH_2COOCH_2CH_2OCOCH_2CH_2$
E) $CH_2CHCOOCH_2CH_2OCOCHCH_2$

16. Which apparatus is needed for a gravity filtration?

A)

D)

B)

E)
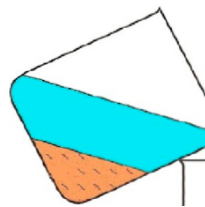
C)

18. The viscosity of water cannot be changed by:
A) Temperature
B) Pressure
C) Addition of detergent
D) Addition of salt
E) None of the above, as a physical property, viscosity cannot be changed.

19. Generally, after a short rain, streaks of color are visible in parking lots and road surfaces. This is caused by
A) interference patterns due to the rain water floating on the oil/gas droppings.
B) interference patterns due to the oil/gas droppings floating on the rain water.
C) water and oil mixing together in an emulsion.
D) the water diluting the oil/gas droppings causing uneven thicknesses.
E) sunlight reflecting off the oil/water mixture.

20. A thin film with index of refraction n_{film} separates two materials, each of which has an index of refraction less than n_{film}. A monochromatic beam of light is incident normally on the film. If the light has wavelength λ within the film, maximum constructive interference between the incident beam and the reflected beam occurs for which of the following film thicknesses?

A) 3λ
B) 2λ
C) λ
D) $\dfrac{\lambda}{2}$
E) $\dfrac{\lambda}{4}$

21. When light passes from air into oil, what happens to the speed and the wavelength of light respectively as it crosses the boundary?

A) Increases / Remains the same
B) Remains the same / Decreases
C) Remains the same / Remains the same
D) Decreases / Increases
E) Decreases / Decreases

22. During an exciting and seemingly magical physics class demonstration, your teacher places a test tube inside a beaker half-filled with baby oil. Then, by slowly pouring this same baby oil into the test tube, the teacher apparently makes the test tube disappear!

Image BEFORE inner test tube is filled with oil. You can even notice typical refractive bending of the test tube. *Original photo: D Taylor 2013.*
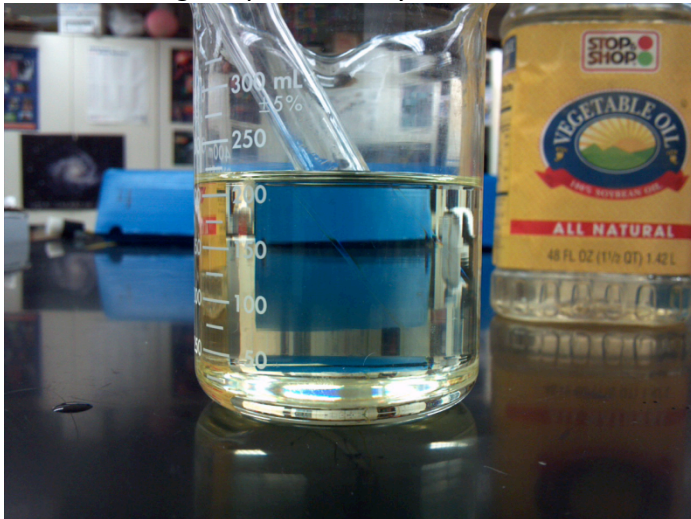

Image AFTER oil is placed inside test tube. *Original photo: D Taylor 2013.*
Which of the following is the best explanation for this?
A) Pyrex has a higher optical index of refraction then does baby oil.
B) Both pyrex and baby oil have the same optical index of refraction.
C) Pyrex has a lower optical index of refraction then does baby oil.
D) This is a trick best performed by skilled "magicians".
E) Refraction cannot occur through both Pyrex and an oilly liquid.

23. Which of the following statements about wastewater treatment is correct?
A) Primary treatment uses microbes.
B) Secondary treatment removes organic wastes.
C) Tertiary treatment uses gravity.
D) Quaternary treatment disposes of sludge.
E) All of the above are correct.

24. Which of the following is NOT currently used to clean up oil spills?
A) bioremediation
B) burning
C) booms
D) dispersants
E) all of the above are used.

25. Which of the following environmental disasters did NOT involve hazardous oil spills or leakage?
A) Fukushima.
B) BP Horizon.
C) Exxon Valdez.
D) Superstorm Sandy.
E) Ixtoc I

26. Most oil pollution of the waterways comes from
   A) offshore drilling accidents.
   B) oil tanker accidents.
   C) runoff from land.
   D) intentional release.
   **E)** oil pipeline leaks.

III. *"In the first report on the uptake and internal processing of triclocarban (TCC) in fish, scientists have reported strong evidence that TCC - an antibacterial ingredient in some soaps and the source of environmental health concerns because of its potential endocrine-disrupting effects -- has a "strong" tendency to bioaccumulate in fish ... Ida Flores, who presented the results, pointed out that all existing evidence indicates that TCC does not bioaccumulate in humans and certain other mammals ... Along with a related ingredient called triclosan, TCC has been the source of controversy in recent years ... Due to its widespread usage [in bar soaps] TCC is present in small amounts in 60 percent of all rivers and streams in the USA ... They exposed one-week-old larvae of medaka fish ... the fish quickly accumulated TCC .. .the levels ... soon after exposure were about 1,000 times higher than the concentration in the water."* ScienceDaily Apr. 1, 2011

27. These TCC findings are a cause for concern because
   A) minute amounts of TCC could build up to toxic levels in the fish.
   B) there is a high concentration of TCC in our waterways.
   C) TCC is a known fish toxin.
   D) TCC is a known human toxin.
   E) TCC might disrupt photosynthesis.

28. A reason that TCC might bioaccumulate in fish but not in humans would be differences in their respective _____ systems.
   A) respiratory
   B) circulatory
   C) digestive
   D) excretory
   E) integumentary

29. A logical next research step would be to study the effect of TCC on fish
   A) growth.
   B) gamete production.
   C) disease resistance.
   D) schooling behavior.
   E) life span.

30. Which of the following has also been shown to bioaccumulate?
   i. DDT
   ii. mercury
   iii. CFCs
   iv. CO_2

   A) only one of the above.
   B) i and ii only.
   C) i and iii only.
   D) i, ii, and iii only.
   E) all of the above.

31. The difference between bioaccumulation and biomagnification is
   A) bioaccumulation only happens in lower trophic levels; biomagnification only happens in upper trophic levels.
   B) biomagnification can occur even if bioaccumulation does not occur.
   C) biomagnification can only occur if bioaccumulation also occurs.
   D) bioaccumulation refers to individual organisms; biomagnification refers to populations.
   **E)** none; these terms are interchangeable.

32. Below is the structure of TCC, 3-(4-Chlorophenyl)-1-(3,4-dichlorophenyl)urea. What functional group is present in this molecule?
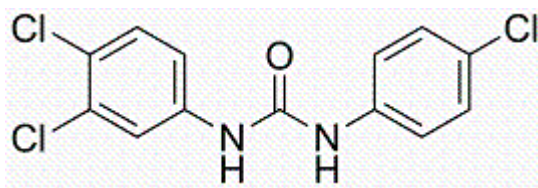
A) ketone
B) carboxylic acid
C) ester
D) ether
E) amide

33. Again referencing the TCC molecular structure, how many atoms can form a hydrogen bond with water?
A) 3
B) 5
C) 6
D) 8
E) all of them

34. Below is the structure of triclosan, 5-chloro-2-(2,4-dichlorophenoxy)phenol. What functional group is present in this molecule?
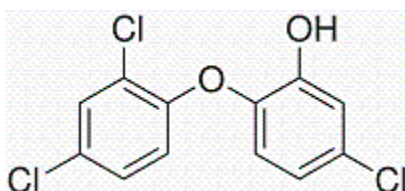
A) ketone
B) carboxylic acid
C) ester
D) ether
E) amide

35. Below is the labeled structure of triclosan, 5-chloro-2-(2,4-dichlorophenoxy)phenol. Using IUPAC naming rules, which atom(s) would be identified as 1?
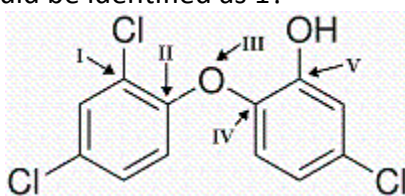
A) I only
B) III only
C) V only
D) II and IV
E) II and V

36. Triclosan is used in a variety of common household products, including soaps, mouthwashes, dish detergents, toothpastes, deodorants, and hand sanitizers. What is its function in toothpaste?

A) flavoring
B) emulsifier
C) prevent gingivitis
D) creates the foam during brushing
E) hardens tooth enamel to prevent decay

IV. *"By examining a set of fossil corals that are as much as 7,000 years old, scientists have dramatically expanded the amount of information available on the El Nino-Southern Oscillation. ... The new coral data show that 20th century El Nino Southern Oscillation (ENSO) climate cycles are significantly stronger than ENSO variations captured in the fossil corals. But the data also reveal large natural variations in past ENSO strength ... ENSO extremes drive changes in global temperature and precipitation patterns every two to seven years... by analyzing the ratio of specific oxygen isotopes in the coral skeletons, the scientists obtained information about ENSO-related temperature and rainfall variations during the period of time in which the corals grew.... The study of each core began with careful dating, done by analyzing the ratio of uranium to thorium."* ScienceDaily Jan 3, 2013

37. An ENSO is a weather pattern that begins
  A) off the coast of Antarctica.
  B) in the Pacific near Hawaii.
  C) in the Atlantic near the Caribbean.
  D) in the southern Indian ocean.
  E) off the Pacific coast of Ecuador.

38. Corals are
  A) extinct unicellular organisms.
  B) marine fish.
  C) marine plants.
  D) sedimentary rocks.
  E) colonial animals.

39. An ENSO begins when
  A) global warming increases ocean temperatures.
  B) prevailing westerly winds weaken.
  C) an unusual number of hurricanes occur.
  D) annual rainfall decreases.
  E) ocean upwelling increases.

40. El Nino is responsible for
  A) severe winters in NJ.
  B) increased rain in California.
  C) increased fish catch in the Pacific.
  D) decreased global temperatures.
  E) increased rain in Australia.

41. An El Nino is detected by
  A) a change in wind patterns.
  B) a decrease in precipitation amounts.
  C) an increase in ocean temperatures.
  D) an increase in ocean current strength.
  E) a decrease in coastal land temperatures.

42. Coral skeletons are mostly composed of
  A) lime
  B) chitin
  C) cartilage
  D) precipitated proteins
  E) insoluble polycarbonates

43. Which have the most influence on the oxygen isotopic composition in the Earth's atmosphere.
  I. carbon cycle
  II. water cycle
  III. nuclear bomb testing

  A) I only
  B) II only
  C) III only
  D) I and II
  E) all three

44. Why was uranium – thorium dating used instead of the usual carbon dating?
   A) The time period was too long for accurate carbon dating.
   B) The time period was too short for accurate carbon dating.
   C) Coral skeletons do not contain carbon.
   D) Carbon dating will only work on wood, natural fibers, and animal tissue.
   E) None of the above.

45. Uranium – thorium involves a ratio of U-234 and Th-230. What is the decay process for U-234
   A) alpha decay
   B) beta decay
   C) gamma emission
   D) electron capture
   E) positron emission

46. The oxygen isotopes being analyzed in the studies are O-16 and O-18. How do they differ?
   A) O-18 has 2 more protons.
   B) O-18 has 2 more neutrons.
   C) O-18 has 2 more electrons.
   D) O-18 has 1 more proton and 1 more neutron.
   E) O-16 is used to make water, O-18 is used to make breathable oxygen.

V. Kepler-62 *It was reported April 14, 2013, via Harvard Center for Astrophysics, that NASA's Kepler mission has found a star system 1,200 light years away with two earth-like planets in what is referred to as the "habitable-zone" of the star. Planet Kepler-62e has a mass of 1.6 earth masses (M_E) and planet Kepler-62f is 1.4 M_E.*
Kepler is designed to detect extra-solar planets using a technique called transit/eclipse-method. This simply means it looks for the evidence that a planet is periodically moving in front of and behind the central star. Keep in mind, Kepler is not a typical telescope that takes optical "pictures". No telescope exists that can take an image of a distance star, not even the vaunted Hubble Telescope. Stars are simply too far away to appear as anything other than small twinkling dots. So, if we can't see stars with telescopes, we certainly can't "see" the much smaller planets orbiting them.
In the four years it has been in space, Kepler has detected 2,740 candidate planets circling stars in our galactic neighborhood. The following dot-graph represents Kepler data for a planet confirmed a while ago, HAT-P-7b.
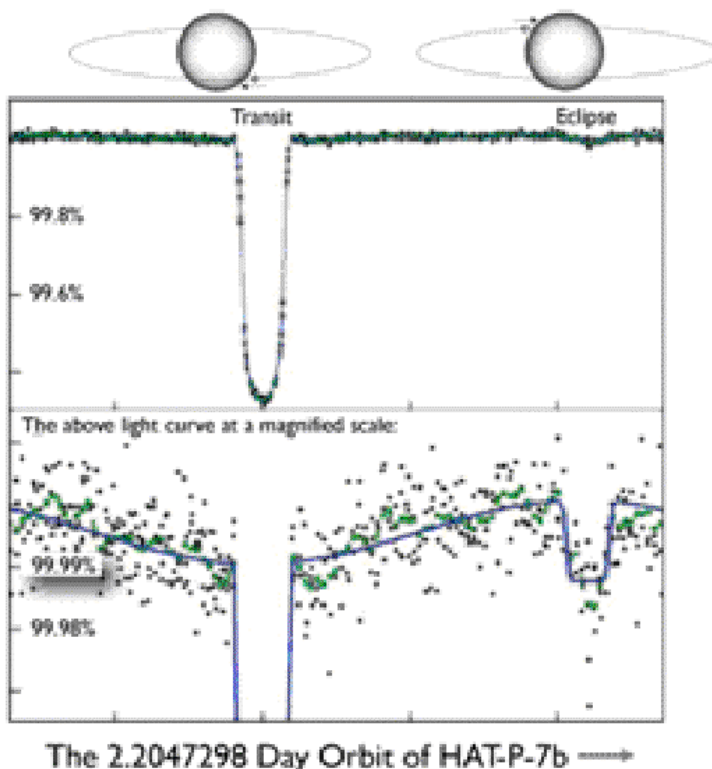

Image courtesy Cornell University Library: Water Planets in the Habitable Zone: Atmospheric Chemistry, Observable Features,
and the case of Kepler-62e and -62f
L. Kaltenegger, D. Sasselov, S. Rugheimer
http://arxiv.org/ftp/arxiv/papers/1304/1304.5058.pdf

47. Based on the introductory statements and the above graph, the vertical axis on the graph represents which quantity?
   A) Time
   B) Size of planet
   C) Light detected
   D) Light blocked
   E) Period of revolution

48. The magnified scale shown on the bottom half of the graph indicates a non-linear relationship both before and after transit. In other words, the graph drops in value approaching transit, then increases in value after transit. It reaches a maximum just before eclipse. Which of the following statements is a viable scientific explanation of this non-linear relationship?

   A) The planet is in retrograde motion.
   B) The planet is slowing down then speeding up.
   C) The elliptical nature of all planets around the central star.
   D) Kepler's detectors are picking up reflected light from the planet.
   E) Kepler's detectors are picking up data from more than one planet at a time.

49. Since Kepler's launch in 2009, it has found 2,740 "candidate" planets. However, as of April 24 2013, there are only 122 *confirmed* Kepler planets. What additional information/data would be needed to confirm the existence of a planet in orbit as opposed to simply some other object passing between the star and Kepler's detectors?

   A) Scientific agreement by consensus.
   B) Confirmation from a Hubble image.
   C) Long-term repeated data that does not deviate.
   D) A few top echelon scientists agree that it is a planet.
   E) Visual confirmation of a planet from ground-based large telescopes.

50. The habitable zone of a star system is generally defined as

   A) the area around a star where astronomers have found life.
   B) the area around a star where a humans could comfortably exist.
   C) the area around a star where only earth-sized or near earth-sized planets can exist.
   D) the area around a star where there is no danger of asteroid or comet collisions with the planet.
   E) the area around a star where a planet has a surface temperature between 0° Cand 100° C thus it could sustain liquid water oceans.

51. By the end of Kepler's 10 year mission, if a star is detected with no light-curve variations as discussed above, is it verified that the star has no planets orbiting it? Choose the answer and reason that best represents how scientists would view this result.

   A) Yes. If there is a planet in orbit, Kepler will "see" it.
   B) Yes. Astronomers know if they don't see something within 10 years, it's not there.
   C) No. This indicates the transit method may be quite flawed.
   D) No. Astronomers, like other scientists, must actually see something to believe it.
   E) No. The orbital plane of the planets is simply not in our line of sight or the planet period is longer than 10 yrs.

52. The factors which help create conditions suitable for life on a planet include
   i. distance from its sun
   ii. type of orbit
   iii. composition of its atmosphere

   A) only one of the above.
   B) i and ii only.
   C) i and iii only.
   D) all of the above.
   E) none of the above.

53. Low mass planets are poor candidates for life formation because they tend to
   A) be too warm for life.
   B) lose their atmosphere quickly.
   C) have rapid plate activity.
   D) have too fast a rotation.
   E) be too far from their sun.

54. The discovery of the existence of which of the following compounds or elements would be most crucial to characterizing a planet as a likely candidate for the presence of living things?
   A) carbon
   B) amino acids
   C) hydrogen
   D) water
   E) oxygen

55. Which of the following chemicals contribute to earth's greenhouse effect, thus making life on earth possible?
   i. oxygen
   ii. carbon dioxide
   iii. water
   A) only one of the above.
   B) i and ii only.
   C) ii and iii only.
   D) all of the above.
   E) none of the above.

VI. *The core drill slides through a drill pipe, extending from the drill ship at the sea surface, through a water depth of 2.5 km and hundreds of metres of sediment, into the ocean crust off the west coast of North America. Microbiologist Mark Lever is on board the Integrated Ocean Drilling Program's research vessel JOIDES. "We're providing the first direct evidence of life in the deeply buried oceanic crust. Our findings suggest that this spatially vast ecosystem is largely supported by chemosysthesis", says Dr. Lever. "There are small veins in the basaltic oceanic crust and water runs through them. The water probably reacts with reduced iron compounds, such as olivine, in the basalt and releases hydrogen...the oceanic crust covers 60 per cent of the Earth's surface. Taking the volume into consideration, this makes it the largest ecosystem on Earth...It is possible that life based on chemosynthesis is found on other planets"... says Dr. Lever.*

from Science Daily 3/18/13

56. Chemosynthetic organisms can obtain their energy from _____ hydrogen or _____ sulfur.
   A) oxidizing...oxidizing
   B) reducing....reducing
   C) reducing....oxidizing
   D) oxidizing... reducing
   E) hydrolyzing....condensing

57. Previous deep ocean floor ecosystems were found
   A) near coastal areas.
   B) off the continental shelves.
   C) along the middle of the ocean.
   D) only in tropical waters.
   E) in estuaries.

58. Chemosythesis is similar to photosynthesis in that

   1. organic compounds are formed in both processes.
   2. ATP is produced in both processes.
   3. Chlorophyll captures energy in both processes.

   A) only one of the above is true.
   B) only 1 and 2 are true.
   C) only 2 and 3 are true.
   D) only 1 and 3 are true.
   E) all of the above are true.

59. In order to prove that the microbes he found were actually living in the oceanic crust and not contaminants of the samples, Dr. Lever needed to

      1. take rock samples many miles deeper than the sea water.
      2. run DNA analysis of the new microbes.
      3. look for oxygen in the water samples.

A) only one of the above was necessary.
B) only 1 and 2 were necessary.
C) only 2 and 3 were necessary.
D) only 1 and 3 were necessary.
E) all of the above were necessary.

60. It would be expected that these new organisms would be most like the
A) methanogens.
B) pathogens.
C) rhodophyta.
D) cyanobacteria.
E) phaeophyta.

61. Dr. Lever hypothesized that these life forms might be similar to possible life forms on other planets. The basis for this statement is
A) these new organisms use an energy source other than the sun.
B) these new organisms are of very old evolutionary origin.
C) these new organisms are able to remain dormant for long periods of time.
D) these new organisms utilize a different genetic code.
E) these new organisms have chemical components typical of extraterrestrial objects.

62. Calculate the pressure exerted by the ocean water on the bottom of the drill shaft 2.5 km below the surface. Assume the density of the salt water at that depth is 1,028 kg/m^3 and g = 10 m/s^2.

A) 1,028 Pa
B) 2,570 Pa
C) 25,700 Pa
D) 10, 280,000 Pa
E) 25,700,000 Pa

63. If a 500-g aluminum rivet $\left(D = 2700 \; kg/m^3 \right)$ loosens and falls out of the drill shaft near the bottom of the ocean, what buoyant force acts on it as it sinks? Use $g = 10 \; m/s^2$.

A) $1.9 \times 10^{-4} N$
B) $0.19 N$
C) $1.9 N$
D) $19 N$
E) $190 N$

64. A service submarine, a little more complex than the one imaged below, is sent to repair the lost aluminum rivet mentioned in the previous question. The viewing window is spherically shaped with center of curvature of 1 meter. The shape is such that it is concave as viewed from inside the submersible and convex as viewed by any fish that happen to swim by. With the lights turned on inside the submersible and virtually total darkness outside the submersible, the engineer can see an inverted real image of her face 75-cm in front of the window surface. How far from the viewing window is the engineer?

- **A)** 25 cm
- **B)** 50 cm
- **C)** 75 cm
- **D)** 100 cm
- **E)** 150 cm

65. What is the pressure (in atm) on the sea floor at 2.5 km (assume no temperature change)?

standard atmospheric pressure	1 atm = 760 mm Hg = 14.7 lbs/in^2
density of sea water	1.03 g/cm^3
density of mercury	13.5 g/cm^3
1 lb.	454 g
1 in.	2.54 cm

- **A)** 25 atm
- **B)** 39 atm
- **C)** 98 atm
- **D)** 250 atm
- **E)** 570 atm

66. Olivine has an elemental composition of 19.3% magnesium, 44.3% iron, , 11.1% silicon, and 25.4% oxygen. A single molecule of it would have a mass of 4.2 x 10^{-22} grams. What is it's molecular formula?

- **A)** $Mg_2Fe_4SiO_2$
- **B)** $Mg_7Fe_{16}Si_4O_9$
- **C)** $Mg_2Fe_2SiO_4$
- **D)** $(MgFe)_4(SiO_4)_8$
- **E)** $MnFe_2SiO_4$

67. Olivine forms an *orthorhombic* crystal. What is the angle in the base of this crystal?

- **A)** 45°
- **B)** 60°
- **C)** 90°
- **D)** 109.5°
- **E)** 120°

68. The basalt formations are generally the result of

- **A)** volcanic eruptions.
- **B)** erosion of the sea floor.
- **C)** pressure of the ocean.
- **D)** crystallization of the salt.
- **E)** precipitation of sea water minerals.

VII. *The EPA today published figures for four key air pollutants reponsible for long-range transboundary air pollution....this latest information ...shows that in 2011, emission of nitrogen oxide (NOx) were above the specified emission ceiling...The figures also show that levels of sulphur(sulfur) dioxide, volatile organic compounds (VOCs) and ammonia were below the EU emission ceilings.*

from EPA releases figures for key air pollutants, 2/26/2013

69. NOx are hazardous to human health because they
    A) cause cancer.
    B) irritate respiratory tracts.
    C) cause cataracts.
    D) decrease immune response.
    E) irritate skin.

70. The most likely cause for the increase in NOx is the
    A) increased number of gasoline burning cars.
    B) increased number of heated homes.
    C) increased number of coal burning factories.
    D) increased human population size.
    E) increased use of nuclear power plants.

71. The probable reason for the reduction in VOCs is the
    A) change in paint formulations.
    B) change in number of vehicles.
    C) increased use of solar power.
    D) increased use of fertilizer.
    E) ban on use of aerosol cans.

72. The four pollutants in this report are responsible for all of the following *except*
    A) acid deposition.
    B) ozone pollution.
    C) eutrophication.
    D) ozone hole depletion.
    E) city smog.

73. All of the following changes in energy source are ways to decrease sulphur (sulfur) emissions *except*
    A) switching from fuel oil to natural gas.
    B) switching from coal to nuclear power.
    C) swiching from coal to fuel oil.
    D) switching from bitumen to anthracite.
    E) switching from fuel oil to solar.

74. NH_3 emissions are are involved in
    1. acid deposition.
    2. the spread of invasive species.
    3. ozone hole depletion.
    4. global climate change.

    A) only one of the above.
    B) 1 and 2 only.
    C) 1 and 3 only
    D) 1 and 4 only
    E) only 3 of the above.

75. In atmospheric chemistry and air pollution, nitrogen oxides (NO_x) generally refer to which compound(s)?
    1. NO
    2. NO_2
    3. N_2O_4
    4. N_2O
    A) only 1
    B) only 1 and 2
    C) only 2 and 3
    D) only 1, 2, and 4
    E) all of the above

VIII. Gamma Ray Bursts (GRB) *Friday 05/03/2013, NASA's Goddard Space Flight Center in Maryland released information on a record-breaking Gamma Ray Burst. The gamma rays detected have energy of at least 94* **GeV**, *more than triple the previous record-holder. Detected by NASA missions Fermi and Swift, these monster flashes of gamma rays are the brightest and most energetic events known in the Universe. Gamma-ray bursts are the universe's most luminous explosions. Astronomers think most occur when massive stars run out of nuclear fuel and collapse under their own weight. As the core collapses into a black hole, jets of material shoot outward at nearly the speed of light. The jets bore all the way through the collapsing star and continue into space, where they interact with gas previously shed by the star and generate bright afterglows that fade with time.*
[The above information can be found at http://www.nasa.gov/topics/universe/features/shocking-burst.html]

Fermi, formally named GLAST for Gamma ray Large Area Space Telescope, is the first detector created that can "see" gamma rays. The problem with detecting gamma rays is they generally will simply travel through any regular electromagnetic detector. In an ingenious technological advancement, one that brought together the astrophysics and particle physics communities, Fermi scientists use what is called particle pair conversion to detect gamma rays and the direction in which those gamma rays came from. The image below is an over-simplification of how this works.

[Image courtesy of: http://fermi.gsfc.nasa.gov/ssc/]
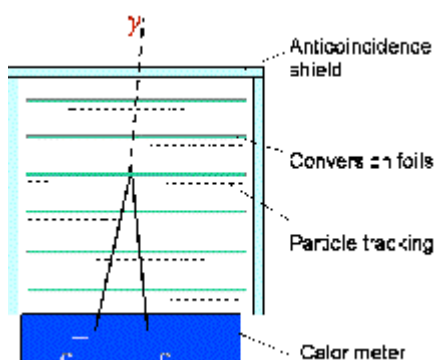
Gamma rays penetrate into the detector and interact with a high "Z converter" material, in this case tungsten, to produce an electron-positron pair. The electron is designated as e⁻ while the positron is e⁺. This pair is tracked through the instrument by silicon strip detectors. By back-tracking the paths of the electron-positron pair in 3-D, the LAT determines the direction of the incoming gamma ray. At the bottom of the LAT is a calorimeter made of CsI(Tl) that is thick enough to provide an adequate energy measurement of the pairs in the LAT energy band. Incidentally, the "anticoincidence shield" at the top is designed to stop incoming cosmic rays that would cause a huge background noise.

76. What differentiates a cosmic ray from a gamma ray?
    A) Both are electromagnetic radiations, but cosmic rays are higher energy than gamma rays.
    B) Both are electromagnetic radiations, but gamma rays are higher energy than cosmic rays.
    C) There is no differentiation. These are two names for the same thing.
    D) Gamma rays are electromagnetic in nature, cosmic rays are not.
    E) Cosmic rays are electromagnetic in nature, gamma rays are not.

77. In pair production, a single gamma photon is converted to an electron-positron pair. Calculate the rest energy of a positron in **eV**.
    A) 5×10^5 eV
    B) 5×10^{-5} eV
    C) 8×10^{-14} eV
    D) 8×10^5 eV
    E) 9×10^{-31} eV

78. Determine the minimum energy of the gamma ray photon that can create an electron-positron pair.
    A) 5×10^5 eV
    B) 1×10^6 eV
    C) 8×10^5 eV
    D) 1.6×10^6 eV
    E) 9×10^{-31} eV

79. Calculate the momentum of one 94 GeV photon.
A) 5×10^{-17} $kg \cdot m/s$
B) 3.1×10^{-17} $kg \cdot m/s$
C) 2×10^{-21} $kg \cdot m/s$
D) 2×10^{21} $kg \cdot m/s$
E) Zero, photons have no momentum.

80. Gamma photon radiation is one of the three basic nuclear radiations; alpha and beta are the other two. Which of the following differentiates gamma radiation from both alpha and beta radiation?

A) Gamma radiation is the only one that is harmful to living organisms.
B) Gamma radiation results in a larger change in the original nucleus' atomic number and mass.
C) Gamma radiation is deflected by magnetic fields while neither alpha nor beta is deflected.
D) Gamma radiation is not deflected by magnetic fields while both alpha and beta are deflected.
E) Unlike natural nuclear decay through alpha and beta radiation, gamma radiation is not found in nature and must be induced in the laboratory or nuclear reactor.

81. Some scientists believe that a gamma ray burst may have caused the Ordovician–Silurian extinction event, the second largest extinction event. During this event the _____ were most affected.
A) dinosaurs
B) anaerobes
C) amphibians
D) corals
E) chondrichthyes.

82. NASA's Goddard Space Flight Center in Greenbelt, MD is named after Dr. Robert Goddard. What is Goddard famous for?
A) The first director of NASA.
B) The first American in space.
C) Creating, building, and launching the first liquid-fueled rocket.
D) Designing the first spacesuit that enabled humans to survive in a vacuum.
E) A US Senator who managed to have the space center built in his home state.

83. CsI(Tl) is thallium activated cesium iodide. Why does this material have high gamma ray stopping power?
A) It dissolves readily in water.
B) It is a cubic crystal with no cleavage.
C) Its has a high density and high atomic number.
D) Its refractive index is close to the wavelength of gamma rays.
E) It has strong ionic bonds due to the interaction of an alkali metal and a halogen.

84. Below is the position of thallium in the periodic table. What would you predict for its properties?

I. oxidation states of +1 and +3
II. soft and a good electrical conductor
III. forms an oxide with the formula of TIO_2

A) I only
B) II only
C) III only
D) I and II only
E) All three

85. Which statements are true concerning the element cesium?
   I. forms an oxidation state of +1
   II. a soft metal
   III. least reactive of its family
   IV. largest atom of its family

   A) I and II only
   B) I and III only
   C) II and IV only
   D) I, II, and IV only
   E) All three

END OF TEST

Merck State Science Day 2013
ADVANCED INTEGRATED
Answer Section

1. E	29. B	57. B
2. B	30. B	58. B
3. C	31. C	59. E
4. B	32. E	60. A
5. A	33. B	61. A
6. C	34. D	62. E
7. B	35. E	63. C
8. A	36. C	64. E
9. D	37. E	65. D
10. B	38. E	66. C
11. B	39. B	67. C
12. C	40. B	68. A
13. B	41. C	69. B
14. D	42. A	70. A
15. B	43. D	71. A
16. A	44. E	72. D
17. ~~C~~ eliminated	45. A	73. C
18. D	46. B	74. ~~B~~ E
19. B	47. C	75. B
20. E	48. ~~C~~ D	76. D
21. E	49. C	77. A
22. B	50. E	78. B
23. B	51. E	79. A
24. E	52. D	80. D
25. A	53. B	81. D
26. C	54. D	82. C
27. A	55. C	83. C
28. D	56. C	84. D
		85. D